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Adaptive Protection Coordination in Distribution System with Distributed Energy Resources-A Review

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***Abstract*-Renewable technology are considered as clean supply of electricity and most fulfilling use of these recourses reduce environmental affects produce the minimum secondary waste and sustainable primarily based on contemporary and destiny monetary. These assets are normally allotted in nature and immediately incorporated at distribution tiers. Increasing penetration of the distributed electricity recourses in distribution strength network create additional operational and manage troubles.**

In energy machine properly coordinated protection scheme is designed to make certain that only the faulty a part of the system could be isolated when abnormal working circumstance of the gadget will reach. The complexity of the system as well as the accelerated user demand and the deregulated environment put in force the utilities to improve machine reliability with the aid of using a well coordinated protection scheme. Therefore new protection coordination scheme are required for presenting the good enough protection coordination for allotted electricity sources connected electric power community. The intention of this review paper is discover the future scope of relay coordination utility for allotted electricity assets related distribution machine.

Keywords: ***Renewable Energy Resources, Relay coordination, Distributed energy resources, Directional over Current Relay and Time dial settings.***

I.INTRODUCTION

Renewable strength assets [RES] are play essential role of source of strength for destiny power requirement in most nations in the global [1].RES are those resources which may be used to provide electricity time and again. E.G. - solar strength, wind strength, biomass electricity, geothermal power and many others. And some other name of the assets are known as opportunity source of power [2].Renewable electricity in India comes beneath the purview of ministry of recent and renewable electricity [MNRE]. India's amongst the world leaders in the renewable strength use and region India on the centre of its global solar alliance challenge selling the increase and improvement of solar strength the world over to over one hundred twenty countries. India's over all set up ability reached 329.4GW with renewable accounting for 57.472GW as of 14 June, 2017.Sixty one% of the renewable power came from the wind while sun contributed nearly19%. Large hydro established potential turned into forty four.41GW as of 28 February, 2017. [3].These assets are relying on site and their sizes varies from few kilowatts to megawatts depending upon the provision and location .Usually electricity generated from them isn't bulk, as evaluate to thermal and nuclear strength plant . Therefore they do not require lengthy energy transmission lines for energy transmission traces for strength generating devices to load centre. RES are emerging as capability source of deliver of electric electricity for rural electrification where atleast 25-30 million human beings but un-electrification inside the rural areas, like usa India.[4] The scenario is in general genuine for different underneath advanced international locations in addition to growing nations within the global.

The most vital undertaking when putting in directional relays at the machine is deciding on their appropriate settings such that their fundamental protective characteristic is met below the requirements of sensitivity, selectivity, reliability and velocity [25]. The over modern-day relay coordination in distribution gadget networks may be very tremendously constraint optimization problems of chasing objective for stepped forward energy machine reliability. Several articles over calculation of the time dial and pick up contemporary ((TDS and Ipu) placing of the relays is the center of the coordination.

1.1Distributed Energy Resources-

The RES are disbursed within the nature and generally included within the distribution in the distribution network and are called dispensed energy sources [DER][1]. Nowadays, integration of disbursed energy sources [DER] in sub transmission and distribution system is growing unexpectedly. It consequences in higher voltage profile, better electricity reliability and reduction in transmission and distribution losses.DER ,small scale electricity generation source located near wherein energy is used [e.G.- a home or business], offer an opportunity to or an enhancement of conventional electric powered electricity grid.DER is quicker ,less expensive choice to creation of big, valuable energy vegetation and excessive voltage transmission line. They offer customers the capacity for lower price, higher energy satisfactory, accelerated energy efficiency and energy independence [5]. More ever, DER is generally renewable in nature and power era from these recourses green and eco –pleasant.

Among different form of DERs, wind and solar are currently maximum promising and their impact at the safety is more seen compared to different form of DERs. It isn't always essential that each one wind generators may be function in a wind farm all time [6]. During some operation state of affairs either whole wind farm may be off or some wind turbines may be off. In monsoon period in India maximum of the wind turbines are in the operation in massive wind farm, even as in wintry weather season most of them are inactive. This seasonal availability of wind causes variable quick circuit feeding skills of wind farms within the almost power networks. However in case solar,

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availability of solar shines hours and climate circumstance is major to feed variable infeed in community. Apart from this, loss of bulk electricity shifting line causes over loading of power traces, when there's large amount of power generation is available from seasonal wind farms and bulk solar energy stations. This problem is addressed in this research article, by using converting the strains parameter of maximum over loaded traces. The change in line parameters not directly contributes to the trade in fault degree in active energy community and especially leads to the miscorridination many of the distance relays and over modern-day relays located at sub transmission stages. In addition to this, fault ranges are also converting because of the line and principal fault feeding source outages inside the power community.

Depending upon the dimensions of DER, their penetration within the distribution system can be categorised as either big scale penetration or small scale penetration whilst they're in megawatt in length; they're usually included with national grid. They can also bring about change of configuration of transmission /distribution community due to their intermittent nature. Power community with strength feeding DERs resources are referred to as active energy community. As cited above, there may be lot of blessings to integrate to combine DERs with energy community immediately but the operation and manage of active energy community s turns into very complicated and challenging for the device operators. It creates incredible issue for protection engineer to redefine the relay settings of relays for converting fault tiers in the active strength community [7, 8]. In this studies article, an adaptive protection scheme is mentioned which updates the settings of the relays for the duration of the operation [9].

1.2 Relay-

The fundamental characteristic of shielding tool in the energy system is to come across and eliminate the chosen faulty components as speedy as possible. Over modern-day relays are widely used for safety of radial sub- transmission device and distribution device and it has low price [7].However their sluggish operating pace is not perfect feature for their software as number one safety scheme for sub transmission system.

The protection scheme that's designed for unidirectional waft of fault modern-day fails to provide the good enough safety coordination while DERs electricity is injected within the distribution machine. For the machine having more than one source connected this is meshed or looped community, directional over current relay [DOCR] grow to be suitable preference for better selectivity. Since DOCR operate simplest whilst the fault modern waft in the precise tripping path desired. DOCR are supplied in electric system to isolate simplest the defective strains inside the occasion of faults within the system. These relay are located at both cease of traces. To hold the continuity of supply to healthful segment and to isolate the healthy section best, relays are coordinated. Their coordination is an crucial issue of the protection gadget layout .Relay coordination trouble is to decide the collection of the relay operation for every feasible fault area in order that faulted phase remoted with enough coordination margins and without immoderate time delays. This collection choice is a feature of strength community topology, relay traits and protection philosophy (Birla et .Al, 2006)[21].

II. LITERATURE REVIEW

A.Rathinam, 2010 defined the main feature of the protective gadgets inside the strength device is to detect and dispose of the selected faulty components as speedy as possible. Directional over modern-day relays are normally used for the protection of interconnected sub transmission structures, distribution structures, or as a secondary safety of transmission structures. For the structures having a couple of source linked, this is meshed or looped networks, directional over modern relays turn out to be the suitable choice for higher selectivity, when you consider that directional relays perform only whilst the fault contemporary flows in the particular tripping direction favored.

This paper calculates the TDS by means of deciding on one of the available choose up current settings as the predetermined fee. The simplex two segment method is used to determine the non-obligatory TDS of the relays. Improvement in the solution is brought via the usage of the particle swarm optimization method to the co-ordination problem for attaining the worldwide most reliable price with less computational time. Sample three bus and 8 bus systems are utilized for evaluating the effects obtained by means of PSO with that of the simplex method. The optimization approach used within the recent times minimizes the operating time of the relays an awful lot, while compared to the opposite techniques. This technique also complements faster solution of coordination system.

In this paper, an optimization methodology is provided to clear up the hassle of coordinating directional overcurrent relays in an interconnected energy gadget. The working time of the relay changed into determined the usage of MATLAB and is determined to be 1.6908s for Three bus gadget and 17.1518s for Eight bus machine. This cost is in addition optimized the usage of Modified Particle Swarm Optimization technique in C#. A Linear Programming problem system was offered in this venture for the most useful coordination of Directional over Current Relays. It is observed that MPSO calls for only 5 particles for the optimization of the goal function. Therefore the proposed algorithm turned into used to reap the superior setting of the operation time of the directional over current relays within the case have a look at system, a 3-bus device and an 8-bus gadget. The operating time values are located to be 1.3233s for three bus gadget and thirteen.097s for 8 bus System. On analyzing these two cases and comparing the consequences with the ones received from MATLAB, it's miles seen that the goal feature of the DOCR relay is minimized. The optimization of the coordination of Directional over present day relays can be similarly progressed by way of considering or formulating new coordination constraints.[29]

Radha Thangaraj, 2010 provide approach of optimization of directional over-current relay (DOCR) settings is an vital trouble in electrical engineering. The optimization model of the hassle turns out to be non-linear and particularly limited in which two settings namely time dial placing (TDS) and

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plug placing (PS) of each relay are considered as decision variables; the sum of the operating instances of all of the number one relays, which might be expected to function with the intention to clear the faults in their corresponding zones, is considered as an objective characteristic. In the present take a look at, three fashions are taken into consideration specifically IEEE 3-bus model, IEEE 4-bus version and IEEE 6-bus model. To resolve the hassle, we've got applied 5 newly advanced versions of differential evolution (DE) known as changed DE variations (MDE1, MDE2, MDE3, MDE4, and MDE5). The results are in comparison with the classical DE set of rules and with five extra algorithms available within the literature; the numerical effects show that the changed DE algorithms outperforms or carry out at par with the other algorithms.

Coordination of directional over-modern-day relay (DOCR) is a frequently arising hassle in the field of electrical engineering, which may be formulated as an optimization problem. The mathematical model of the trouble is enormously complicated and nonlinear in nature, difficulty to diverse constraints, and calls for sophisticated optimization strategies for its answer. In this paper, an try is made to solve the IEEE three-bus, 4-bus and six- bus models with the assist of primary DE and its modified variations. Five stepped forward versions viz. MDE1, MDE2, MDE3, MDE4 and MDE5 are advised and used to remedy the above cited DOCR trouble. Empirical analysis of numerical consequences obtained by MDE schemes and other algorithms (primary DE, RST2, GA, SOMA, SOMGA, LX-POL and LX-PM) show the competence of the proposed algorithms. Moreover, MDE schemes require simplest one manage parameter i.E. The crossover price (Cr), while most of the other strategies have more than one manage parameters, which are to be high-quality tuned for the a hit overall performance of an set of rules. Among the MDE schemes, the authors could suggest the use of MDE4 and MDE5 schemes for solving the complex type of problems mentioned inside the gift take a look at. In future, work may be achieved at the improvement of an adaptive crossover fee, a good way to make MDE a totally parameter free set of rules.[32]

Manohar Singh, 2017, centered on emission of greenhouse gases and depletion of fossil gasoline reserves are two key drivers, which are forcing the mankind to generate the destiny energy call for from the renewable strength assets. These assets are commonly allotted in nature and are immediately included at distribution levels. Increasing penetration of the dispensed energy sources in distribution power networks creates additional operational and manage issues. These are by and large regulatory, reasonable load dispatching, energy first-rate and safety issues. Generally strength distribution structures are protected with the assist of devoted over contemporary primarily based safety schemes. But growing percentage of dispensed power sources penetration in electric utilities poses a serious chance to the prevailing safety coordination schemes of the distribution structures. Distributed power sources linked distribution networks become interconnected in nature and protection coordination schemes, which can be designed for unidirectional float of fault currents grow to be useless/non-purposeful. Therefore, new protection coordination Schemes are required for supplying the ok safety coordination for dispensed power assets related electric electricity networks. In the to be had literature, the protection coordination schemes for radial distribution systems and tendencies in the region of protection coordination are mentioned in element. A thorough review for these kind of safety coordination schemes for distribution structures with and with out dispensed power sources is completed in this review article. It includes the analytical and artificial intelligence based totally techniques utility for coordination of protecting relays inside the distribution systems. The obstacles and research gaps in the location of protection coordination schemes also are supplied in this evaluation article. The intention of this research paper is to convey all of the to be had studies inside the area of relay coordination on one platform, to be able to assist the rising researcher to identify the destiny scope of relay coordination utility for disbursed power assets related distribution structures. In this evaluation article, a detailed literature evaluate for safety coordination for distribution systems with and without DER is discussed. This assessment article covers the assessment of all of the superb protection coordination strategies beginning from the initial curve becoming, graph theory and application of precise optimization equipment for fixing the protection coordination theory and alertness of precise optimization tools for solving the protection coordination problem for radial/ interconnected power systems. In those strategies, the relay coordination problem is formulated as linear and non-linear optimization hassle after which solved the usage of the distinctive optimization strategies. These included, precise method and artificial intelligence primarily based optimizations methods.[30]

Penetration of DER in distribution systems creates new safety coordination problems. Their impact at the community protection particularly relies upon upon their size and location and impact may be labeled as huge scale penetration or small scale penetration. Large scale penetration outcomes in bidirectional go with the flow of fault modern-day over the most feeders. The present unidirectional designed safety coordination schemes fail to clean the fault for such fault situations. In the available literature, these troubles are addressed via localizing the DER effect and updating the protection setting wherever required. Therefore this evaluation article makes a compressive evaluate of all of the protection schemes which might be discussed in literature for maintaining the safety coordination below DER integration. Review is also extended safety problems springing up in restrained penetration of DER in electricity network and islanding mode of operation of energy structures. In this assessment article, seen studies gaps and feasible future scope of research in safety coordination has been also provided.

The numerous different studies papers are overview by using the author about the coordination of the relay that's offered within the paper [24, 26, 27, 28].

III. PROTECTION COORDINATION STUDIES FOR RADIAL DISTRIBUTION SYSTEM

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The various method and technique which have been used in development of relay coordination can be categories as under-

2.1 Curve Fitting Technique-

The relay characteristics need to be modeled and stored in computer memory for performing relay coordination. Researcher have made many attempts in past to model relay characteristics. From these modeled time inverse characteristics, time dial settings and operating time of the over current relays calculated. The curve fitting technique is used for determining the best function to represent data. The relay characteristics are modeled mathematically by polynomial from using curve fitting technique. [10-12].

Curve fitting techniques are simple techniques for setting of the relays but they are inaccurate for current settings less than 1.3 times of pick-up current.

2.2Graph Theory Technique-

Extensive research had been done on the application of graph theory for the protection coordination studies[13-18].they utilize the network structure for analyzing the information about the minimum set of break points, the sequence for the settings of the relays and line directionality for directional relays.

Graph theory technique is quite useful for solving the relay coordination problem were discussed.

2.3Optimization Techniques-

The use of optimization technique in relay coordination was first suggested by Uradaneta et al [1988]. In this paper two techniques were proposed for solving the time inverse over current relay coordination problem. First technique was applicable for fixed network configuration and second one was for variable network configuration. The time dial settings [TDS] determination in interconnected power system has been described as an optimization problem [19].In general DOCR relay allow for continuous TDS but discrete pick up current settings [I_p]. In referred study, however both TDS and I_p were assumed continuous variable, in order to avoid the use of mixed non linear programming technique. Linear programming methods were simple and easily converge to optimal solution. The linear programming methods were simple and easily converge to optimal solution. The linear programming technique like – simplex, two phase simplex and dual simplex and big-M (penalty) methods have been tried in performing the coordination of over current relays.

Rosenbrock-hill climb method of nonlinear programming has been used for optimal setting of pick up current [20] and Birla et .al [2005] also made an attempt to use "Mat Lab Toolbox And Numeric Algorithm Group ''sequential quadratic programming routines. Application of random search technique [RST] for solving relay coordination problems are also discussed in [21].evolutionary programming is multi point searching optimization algorithm. Optimization technique based on evolutionary programming also has been reported in this paper [22].

III. PROTECTION COORDINATION FOR DISTRIBUTION SYSTEM WITH DER

The various method and technique which are used in development of relay coordination with DER-

1- General protection scheme
2- Multi- agent based protection scheme
3- Expert system based protection scheme
4- Dual setting protection scheme

Above mention method which is describe in detail in the paper [23]. This is helpful in relay coordination.

IV.OBJECTIVE FUNCTION AND CONSTRAINT OF THE PROBLEM FORMULATION

Time dial setting (TDS) and plug settings (PS) of each over current relays are obtained by solving the relay coordination problem. The relay coordination problem is formulated as non-linear optimization problem in which fitness function (J) is summation of operating time of all primary relays and CTI violations.

The mathematical expression for the fitness function is given as [27].

$$J = \min.\left[\left(\alpha_1 * \sum_{i=1}^{N_r} T_{i,k}\right) + \sum_{P=1}^{PR} (\text{Penality})^P\right] \quad (1)$$

α_1 is weighting factor for minimising the total operating time of all primary relays. Nr is total number of relays. PR is number of primary/backup relay pairs. Operating time of an over current relays is non-linear function of TDS and PS as under

$$T_{i,k} = TDS * \left[\frac{\alpha}{(M)^{\beta} - 1} + L\right] \quad (2)$$

Where α and β are the relay constants as per International Electro Technical Commission (IEC) standard [33]. Their values are 0.14and 0.02, respectively, for a standard time inverse over current relay. The expression for plug setting multiplier (M) is given as

$$M = \frac{I_{fl}}{I_{pick}} \quad (3)$$

The second term in (1) maintains the CTI greater than 0.2 s. If CTI is below 0.2 s, a very high penalty is generated as per (4) and is added in the fitness function given in (1). If there is no CTI violation, then zero penalties are added in (1) as per (4). In this way penalty is calculated for each primary/backup over current relay pair 'PR'. The expression for k is given in (5).

$$\text{Penality} = \{k, \forall \Delta t_{mb,k} < 0.2, \quad else 0 \quad (4)$$

$$k = \alpha_2 * |0.2 - \Delta t_{mb,k}|^2 * (\Delta t_{mb,k} < 0.2) \quad (5)$$

Where $\Delta t_{mb,k}$ is selectivity margin and also known as CTI and α_2 is weighting parameter used for controlling lower limit of CTI above0.2 s.

The optimal coordination problem of DOCR using optimization technique consists of minimizing an objective function subject to certain coordination criteria and limits on problem variable. The relay which is operating first to clear the fault is called the primary relay. A fault close to relay is

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known as the close-in fault for relay and a fault at the other end of lines is known as far- bus fault for the relay. Conventionally, objective function in coordination studies is constituted as summation of operating time of all primary relays, responding to clear all close-in and far-bus faults.

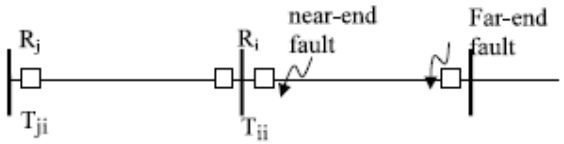

Fig.1 An illustrative diagram for basic definition

The objective function is defined as follows-

$$\text{Minimize Objective} = \sum_{i=1}^{N_{cl}} T^{i}_{pri_{cl_{in}}} + \sum_{j=1}^{N_{far}} T^{i}_{pri\ far_{bus}} \quad (6)$$

Where, cl_in =close in fault or near-end fault, N_{cl}= number of relays responding for close-in fault. $N_{far=}$ number of relays responding for far-bus fault or far-end fault. $T^{i}_{pri\_cl\_in}$ is primary relay operating time for close-in fault. $T^{i}_{pri\_far\_bus}$ is primary relay operating time for far bus fault.

The main constraints under which the fitness function mentioned in (1) is minimised are as under:

1-Bounds on the variables TDSs

$$TDS^{i}_{min} \le TDS^{i} \le TDS^{i}_{max}$$

$$0.1 \le TDS^{i} \le 1.1$$

2-Bounds on the variables PS

$$PS^{i}_{min} \le PS_{i} \le PS^{i}_{max}$$

$$0.5 \le PS^{i} \le 2.5$$

Relay characteristic, bounds on pickup (Ip) current setting of each relay

$$I_P = PS_i * I^{i}_{RC}$$

$$I^{min}_{i} \le I_P \le I^{max}_{i}$$

I^{i}_{RC} is relay rated current rating . This value is usually 1 or 5 A. Lower limit of pickup current (I^{min}_{i}) is 1.5 times more than maximum load current and upper limit of pickup current(I^{max}_{i}) is 2/3rd of minimum three phase short circuit current.

3-limits on the primary operation times

$$0.05 \le T^{i}_{pri\_cl\_in} \le 1.0$$

$$0.05 \le T^{i}_{pri\_far\_bus} \le 1.0$$

4-selectivity constraints for all the relay pairs

Fault is sensed by both primary as well as backup over current relays simultaneously. To avoid mal-operation in the over current relay coordination studies, the backup over current relay should trip only if primary overcurrent relay fails to trip.

$$T_{j,k} - T_{i,k} \ge \Delta\ t_{mb,k}$$

In the proposed relay over current coordination problem the CTI is taken as 0.2 s. k signifies the fault location.

IV. CONCLUSION

A comprehensive review of Overcurrent relay coordination techniques is presented in this paper. In literature many methods and techniques are proposed and implemented to solve relay coordination problem. Starting from initial curve fitting, graph theory and optimization technique discussed for radial/interconnected power system is discussed. In this technique the relay coordination problem is categorize in to linear and non linear optimization problem and solve using different optimization technique. It has been observed that the proper selection of primary and back up protection and maintaining a small time delay between primary and backup relays operation reduces the mal-operation of relays.

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